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AUTHOR Szul, Linda; Berry, Louis
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ABSTRACT

As the use of computers has become more common in society, human engineering and ergonomics have lagged behind the sciences which developed the equipment. Some research has been done in the past on the effects of screen colors on computer use efficiency, but results were inconclusive. This paper describes a study of the impact of screen color configuration on operators' ability to detect typographical errors in text. Participants included 97 undergraduate business students, divided into 3 ability levels--beginning (N=20), intermediate (N=32), and advanced (N=45)--based upon their reported keyboarding experience. Color configurations tested were white text on blue, blue on white, amber on green, and green on amber, all common color configurations in popular word processors. Screen areas were defined in quadrants, moving from upper left (1) to upper right (2), and then lower left (3) to lower right (4). Significant differences in the impact of color configuration were found in advanced and beginning level keyboardists, but none was found in those of intermediate skill level. Results suggested that more errors go undetected in the lower half of the screen, quadrants three and four. The best color configurations for error detection in these two quadrants are W/B and A/G, both light characters on dark backgrounds. These results have direct implications for instructors of proofreading. (Contains 15 references and 5 tables.) (SWC)

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Title:

Color Variations In Screen Text: Effects On Proofreading

Authors:

Linda Szul
Indiana University of Pennsylvania

and

Louis Berry
University of Pittsburgh

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BACKGROUND

As the use of computers has become increasingly common in society, the number of people working with video display terminals has risen dramatically. The computer operator, possibly the weakest link in the computer's productivity, has been frequently overlooked by manufacturers and software developers. Human engineering and ergonomics are in a relatively primitive state compared with the physical sciences that created the equipment.

One important aspect of this interaction between the operator and the computer is the area of screen layout and design, and a question primary to good design is that of the color configuration of the screen text itself. Color has been identified as being an important design consideration (Dwyer, 1972), but variations in the configuration of color have received less conclusive research attention. Taylor and Murch (I986) considered both text and graphic displays when reviewmg the principles for effective color coding on video morntors. They caution that both background and text colors must be considered and that the relative degree of saturation is a critical factor. The concept of perceived brightness and saturation of color has been researched by a number of investigators with sometimes conflicting and contradictory results (Stanton, 1992; Lippert 1985; Wald, 1967). Joyner (I992) concluded that amber text on green was the most effective for reducing errors in document proofreading.

Research on the use of color in improving the usability of a screen display has also provided conflicting results. Kopala (I981) and Sidorsky (I982) found color to be a positive factor while Tullis (1981) and Christ & Teicher (1973) found color to impair performance. Joyner (1989) found keyboard error detection unaffected by color. Other researchers have investigated the effectiveness of variations in color contrast, again, with mixed results (Schnure, 1996; Edstrom, 1987; Gruning, 1985; Lalomia & Happ, 1987). Clearly, the often contradictory findings of these studies emphasize the need for more systematic investigation of the factor of screen text color configuration, particularly with regard to the characteristics of the particular user and user's experience with a video display terminal.

This study was conducted to determine the effect of the color configuration of a video display terminal (VDT) on the operator's ability to detect typographical effors in keyboarded copy. Two primary research questions were addressed: (1) Is there an interaction between keyboarding experience and the color configuration of the VDT in terms of proofreading ability, and (2) Is there a relationship between the color configuration of the VDT and the location of undetected keyboarded errors on the screen.

METHODS AND PROCEDURES

The research sample in the study consisted of 97 undergraduate students enrolled in a college of business at a Pennsylvana university. To assure an accurate representation of varied ability levels and ages, participants were drawn from two regional campuses as well as the main campus. Subjects were subsequently divided into 3 ability level groups--beginning, intermediate, and advanced--based upon their reported keyboarding experience.

The design employed in this study was a 3 x 4 repeated measures design that compared three ability levels across four color configurations: (1) white text on blue background, (2) blue text on white background, (3) green text on amber background, and (4) amber text on green background. Each treatment condition reflected commonly used color configurations used in popular word processing packages.

The materials developed for the study consisted of four business documents containing similar numbers of typographical and layout errors, equally distributed in all four quadrants of the screen. The documents were created using a popular word processing package and were drawn from a departmental exemption examination used in a keyboarding and document formatting class.

Each subject was presented with the four documents in a controlled laboratory environment and was instructed to locate and mark the errors using the overstrike feature of the word processing package. Ten minutes were provided for work on each document. All documents were rotated through each treatment at each campus location to ensure that every subject received all treatment conditions.

FINDINGS AND RESULTS

Using the tabulated data, an analysis of variance for repeated measures was conducted on the treatments by experience levels to test the first research question: Is there an interaction between keyboarding experience and color configuration of the video display terminal in terms of proofreading ability? The results of that analysis revealed a significant interaction ($F=3.504$; $p=.0023$). See Table 1.

Table 1.
ANALYSIS OF VARIANCE ON TREATMENTS BY EXERIENCE LEVELS

Source	df	Sum of Squares	Mean Square	F Value	p Value
Experience Level (A)	2	14.117	7.058	3.761	.0268
Color Configuration (B)	3	8.894	2.965	1.094	.3518
Experience x Color (AB)	6	56.951	9.492	3.504	.0023
Error	282	763.904	2.709		

The means and standard deviations for all color confgurations and experience levels is presented in table 2.

Table 2
TABLE OF MEANS AND STANDARD DEVIATIONS
FOR COLOR CONFIGURATION BY EXPERIENCE LEVEL

Color Configuration	WhiteText/Blue Background		Blue Text/ White Background	
	Mean	SD	Mean	S.D.
Advanced Level N=45	4.111	1.668	4.444	1.531
Intermediate Level N=32	3.406	1.563	3.156	1.439
Beginning Level N=20	3.65	1.461	2.221	2.221
Totals N=97	3.784	1.609	3.773	1.765

Table 2 (Continued)

Color Configuation	Green Text/ Amber Background		Amber Text/ Green Background		Totals		
	Mean	S.D.	Mean	S.D.	N	Mean	S.D.
Advanced Level N=45	3.689	1.635	3.022	1.215	180	3.817	1.601
Intermediate Level N=32	3.469	1.646	3.5	1.606	128	3.383	1.553
Beginning Level N=20	3.3	1.593	4.25	1.552	80	3.612	1.747
Totals N=97	3.536	1.621	3.433	1.485	388	3.433	1.63

Pair-wise comparisons of all means via the Fisher Protected Least Significant Differences Test (PLSD) indicated that for advanced level subjects either white text or blue text was significantly better than any green or amber formats. In

contrast, the multiple comparison tests indicated that beginning level subjects performed significantly better with the amber text on green. Significant comparisons are presented in Table 3.

Table 3.
SIGNIFICANT POST-HOC COMPARISONS OF TREATMENTS
BY LEVELS OF EXPERIENCE
($p < .05$)

COMPARISON	MEAN DIFFERENCE	FISHER PLSD	DECISION
Adv White/Blue vs Adv Amber/Green	.1.089	.656	Adv White/Blue > Adv Amber/Green
Adv White/Blue vs Int Blue/White	.955	.719	Adv White/Blue > Int Blue/White
Adv White/Blue vs Beg Blue/White	.861	.836	Adv White/Blue > Beg Blue/White
Adv Blue/White vs Adv Green/Amber	.756	.656	Adv Blue/White > Adv Green/Amber
Adv Blue/White vs Adv Amber/Green	1.422	.656	Adv Blue/White > Adv Amber/Green
Adv Blue/White vs Int White/Blue	1.038	.719	Adv Blue/White > Int White/Blue
Adv Blue/White vs Int Blue/White	1.288	.719	Adv Blue/White > Int Blue/White
Adv Blue/White vs Int Green/Amber	.976	.719	Adv Blue/White > Int Green/Amber
Adv Blue/White vs Int Amber/Green	.944	.719	Adv Blue/White > Int Amber/Green
Adv Blue/White vs Beg Blue/White	1.194	.836	Adv Blue/White > Beg Blue/White
Adv Blue/White vs Beg Green/Amber	1.144	.836	Adv Blue/White > Beg Green/Amber
Adv Green/Amber vs Adv Amber/Green	.667	.656	Adv Green/Amber > Adv Amber/Green
Adv Amber/Green vs Beg Amber/Green	1.228	.836	Adv Amber/Green < Beg Amber/Green
Int Blue/White vs Beg Amber/Green	1.094	.886	Int Blue/White < Beg Amber/Green
Beg White/Blue vs Beg Amber/Green	1.000	.983	Beg White/Blue < Beg Amber/Green

Since a significant interaction was found, research queston 1 is answered in the affimative. A significant interaction does exist between keyboarding experience level and the color configuration of the video display terminal in terms of proofreading ability. The interaction data is displayed graphically in Figure 1.

Analysis of data strongly suggest that experienced keyboarders will demonstrate greater success in proofreading when working with either blue or white text. The findings of several other researchers have indicated that dark spectrum colors make better background choices and this study supports that conclusion with regard to the use of white text on a blue background with experienced keyboarders. On the other hand, research that suggests that amber text on green is superior may only apply to beginning level or inexperienced users.

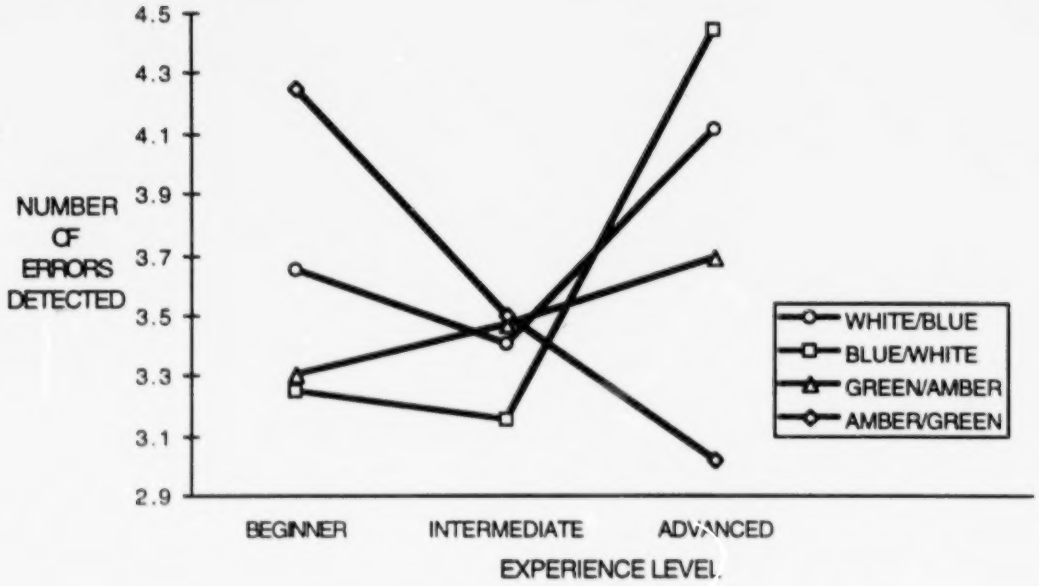

Fig 1.

Interaction Data

Analysis of data related to research question 2: Is there a relationship between the color configuration of the video display and the location of undetected keyboarded errors on the screen, was addressed via analysis of variance of the mean numbers of undetected effors in each of the four screen quadrants. An analysis of Quadrant 1 data did not produce a significant effect (F=1.349, p=.2587). Similarly, analysis of Quadrant 2 data did not produce a significant effect (F=1.152, p=.3286).

The analysis of Quadrant 3 data did reveal a significant treatment effect (F = 3.433,p =.0175). Further analysis of all possible pair-wise comparisons via the Fisher Protected Least Significant Difference Test (PLSD) was conducted. Significant comparisons are presented in Table 4.

Table 4.
SIGNIFICANT POST-HOC COMPARISONS OF TREATMENTS
ON QUADRANT 3 ERROR DATA
($p < .05$)

COMPARISON	MEAN DIFFERENCE	FISHER PLSD	DECISION
Green/Amber vs White/Blue	.206	.167	Green/Amber > White/Blue
Blue/White vs White/Blue	.247	.167	Blue/White > White/Blue

Significantly fewer undetected errors occurred in Quadrant 3 when the color configuration was White/Blue rather than Green/Amber or Blue/White.

An analysis of the data related to quadrant 4 produced a significant treatment effect (F=7.343 p=.0001). Further analysis of all possible pair-wise comparisons via the Fisher Protected Least Significant Difference Test (PLSD) was conducted. Significant comparisons are presented in Table 5.

Table 5.
SIGNIFICANT POST-HOC COMPARISONS OF TREATMENTS
ON QUADRANT 4 ERROR DATA
($p < .05$)

COMPARISON	MEAN DIFFERENCE	FISHER PLSD	DECISION
White/Blue vs Blue/White	.227	.151	White/Blue < Blue/White
White/Blue vs Green/Amber	.278	.151	White/Blue < Green/Amber
Blue/White vs Amber/Green	.216	.151	Blue/White > Amber/Green
Green/Amber vs Amber/Green	.268	.151	Green/Amber>Amber/Green

These comparisons indicated that both White/Blue and Amber/Green formats were significantly more effective in reducing the number of undetected errors in the fourth quadrant. Of particular interest is the fact that both of these formats consisted of light text on a dark background, a fact which may have made the text more distinct and consequently more effective.

The quadrant data also suggests that the greatest number of undetected errors occured in the third and fourth (lower) quadrants of the screen. This may be explained by eye movement studies which demonstrate that the least time is spent viewing this area.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations that follow are based on the findings of this study and may serve as guidelines for future research.

1. Since there is a significant difference in the proofreading abilities of keyboarders possessing advanced levels of keyboarding experience when different color configurations are used, the color configuration of the video display terminal is critical. The most effective color configuration for advanced ability keyboarders appears to be blue text on a white background. Beginning level keyboarders seem to work most effectively when using amber text on a green background. No particular screen configuration seems to assist keyboarders with intermediate level skills.

2. The proofreading ability of the keyboarder increases in proportion to his or her experience level. Individuals with the most keyboarding experience are better proofreaders.

3. The location of the error within a particular quadrant of the screen will determine the relative probability with which the error is detected by the operator. The results indicate that more errors go undetected in the lower half of the screen (Quadrants 3 & 4) than in the upper half of the screen (Quadrants I & 2). These results are in agreement with findings of other researchers who have shown that the eye moves from the upper left corner of the display and scans from left to right, starting at the top. This visual scanning follows the same general ordered pattern as that used in reading printed text. Thus the results have direct implications for the instructor as proofreading techniques are taught

4. White/Blue and Amber/Green configurations appear to be most effective in helping users detect errors in the lower two quadrants. These both represent light text on dark backgrounds which may make the text more distinct. It would appear that particular attention should be given to making text in these quadrants as distinctive as possible to compensate for this apparent disparity in color effectiveness.

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